DETAILED STUDY OF THE 22 MAY 2002 ROCKFALL INCIDENT ON SLOPE NO. 11NE-A/C284 AT SHATIN PASS ROAD TSZ WAN SHAN

GEO REPORT No. 156

Halcrow China Limited

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION

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This report was originally produced in October 2002 as GEO Landslide Study Report No. LSR 9/2002

First published, January 2005

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication. These include guidance documents and results of comprehensive reviews. These publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
January 2005

FOREWORD

This report presents the findings of a detailed study of a rockfall incident (GEO Incident No. 2002/05/0030) which occurred on the evening of 22 May 2002 on a rock cut slope at Shatin Pass Road, Tsz Wan Shan, Kowloon. The incident involved the detachment of rock blocks from a height of 7 m to 8 m above the slope toe at the eastern end of the subject slope. The rockfall was about 7 m^3 in volume, and the rockfall debris was deposited onto Shatin Pass Road resulting in complete blockage of the road. No casualties were reported as a result of the incident.

The key objectives of the detailed study were to document the facts about the incident, present relevant background information and establish the probable causes of the failure. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 2002 Landslide Investigation Consultancy for landslides occurring in Hong Kong Island and Outlying Islands in 2002, for the Geotechnical Engineering Office, Civil Engineering Department, under Agreement No. CE 86/2001 (GE). This is one of a series of reports produced during the consultancy by Halcrow China Limited.

Dr X D Pan
Project Director
Halcrow China Limited

Agreement No. CE 86/2001 (GE)
Study of Landslides Occurring in Hong Kong Island and Outlying Islands in 2002 – Feasibility Study

CONTENTS

1. INTRODUCTION

At about 8:30 p.m. on 22 May 2002, a rockfall incident (GEO Incident No. 2002/05/0030) occurred on rock cut slope No. 11NE-A/C284 at Shatin Pass Road, Tsz Wan Shan, Kowloon (Figure 1 and Plate 1). The incident involved the detachment of rock blocks from a height of 7 m to 8 m above the slope toe at the eastern end of the subject slope (Plate 2). The rockfall was about 7 m^3 in volume, and the rockfall debris was deposited onto Shatin Pass Road resulting in complete blockage of the road (Plate 3). No casualties were reported as a result of the incident.

Following the incident, Halcrow China Limited (HCL), the 2002 Landslide Investigation Consultants, carried out a detailed study of the failure for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 86/2001 (GE).

The key objectives of the detailed study were to document the facts about the incident, present relevant background information and establish the probable causes of the failure. Recommendations for follow-up actions are reported separately.

This report presents the findings of the detailed study, which comprised the following key tasks:

(a) review of relevant documentary records relating to the history of the site,

(b) geological mapping, detailed observations and measurements at the landslide site,

(c) aerial photograph interpretation (API),

(d) limited ground investigation,

(e) analysis of rainfall data, and

(f) diagnosis of the probable causes of the landslide.

2. THE SITE

A site plan of slope No. 11NE-A/C284 is presented in Figure 2 and general views of the slope are shown in Plates 4 and 5. The rock cut slope is about 75 m long with a maximum height of about 12 m and is inclined at an average angle of about 80º towards the south. At the eastern end of the slope, there is a reinforced concrete bridge over a natural drainage line (Figure 1). The western portion of the slope is covered with wire mesh netting, whereas a patch of shotcrete of 3 m by 4 m is present at the eastern crest of the slope. The remaining slope surface is a bare rock cut without surface protection. The natural hillside above the slope crest is inclined at angles of about 50° to 60° and is covered with vegetation and areas of exposed rock and boulders.

At the western end of the subject slope, there is a 225 mm U-channel of about 7 m long along the slope toe. No drainage channel is provided directly above the slope crest. Further up the natural hillside, about 5 m to 20 m to the north of the slope crest, there is a degraded unlined ditch of approximately 600 mm wide which is blocked with topsoil in places. The unlined ditch is connected to a concrete lined channel and an unlined drainage channel at the eastern and western ends of the slope respectively (see Figure 2 and Plate 5).

According to the Slope Information System (SIS), there are no water-carrying services in the vicinity of the slope.

Sheet 11 of the Hong Kong Geological Survey 1:20 000 scale map series HGM20 (GCO, 1986) indicates that the solid geology of slope No. 11NE-A/C284 and the surrounding areas comprise fine- to medium-grained granite intruded by a series of northwest to southeast trending minor rhyolite dykes (Figure 3). A southwest to northeast trending fault is identified on the map sheet following the alignment of the prominent drainage line located at the eastern end of the subject slope (Figure 1). The site is located in a geologically complex area close to a number of plutons, faults and the associated quartz monzonite intrusions.

3. MAINTENANCE RESPONSIBILITY

According to the Slope Maintenance Responsibility Information System of the Lands Department, slope No. 11NE-A/C284 is under the maintenance responsibility of the Highways Department (HyD).

4. RECORDED INSTABILITIES

4.1 Past Instabilities

Based on GEO's landslide database, one landslide (GEO Incident No. K2000/4/4) occurred on slope No. 11NE-A/C284, and the incident was reported to the GEO on 6 April 2000 by HyD. The landslide involved the detachment of 3 to 5 rock blocks, with a total volume of about 0.25 m^3, from the middle portion of the subject slope. No blockage of the road and no casualties were reported as a result of the rockfall. As noted in the GEO's Incident Report, seepage was recorded at the location of the failure and loose boulders and undesirable vegetation were observed above the failure scar. Insufficient maintenance was noted in the GEO's Incident Report to be one of the possible contributory factors of the failure. Following the incident, urgent slope repair works comprising removal of loose boulders and provision of wire mesh netting covering the western portion of the slope were recommended to HyD by the GEO. Based on the photographs attached to the Incident Report, taken at the time of the inspection, the location of the failure is identified and presented in Figure 2.

The GEO's Natural Terrain Landslide Inventory (NTLI) indicated that a previous landslide occurred on the natural hillside about 100 m to the east of slope No. 11NE-A/C284 (Figure 4). The landslide scar could be observed in 1973 aerial photographs with scar width less than 20 m in length. The landslide debris had a runout distance of about 50 m.

4.2 Instabilities Along and Near Shatin Pass Road

According to GEO Landslide Database, a total of 16 landslide incidents occurred on slopes along Shatin Pass Road, which is about 1 km long, between 1986 and 2000. As indicated in the GEO's Incident Reports, all the reported landslides were classified as 'minor' in terms of volume, with a maximum volume of 45 m^3. Among them, five incidents involved rockfalls with a maximum failure volume of 0.25 m^3. The approximate locations of these incidents are shown in Figure 4.

After the 22 May 2002 rockfall incident on slope No. 11NE-A/C284, there were two rockfall incidents that occurred on other cut slopes along or in the vicinity of Shatin Pass Road; one incident occurred on slope No. 7SE-C/C574 (GEO Incident No. 2002/07/0051) at Jat's Incline on 26 July 2002 and the other incident occurred on slope No. 11NE-A/C479 (GEO Incident No. 2002/08/0073) at Shatin Pass Road on 12 August 2002. The approximate locations of these incidents are shown in Figure 4. The rockfall incident at Jat's Incline involved the detachment of rock blocks of about 3 m^3 in volume from 1 m above the slope toe. The rockfall debris was deposited onto the side of the Jat's Incline resulting in complete blockage of the road. The rockfall incident at Shatin Pass Road was relatively minor in nature with debris volume of about 0.5 m^3. No road closure was required as a result of this incident.

5. AERIAL PHOTOGRAPH INTERPRETATION

An API was carried out by HCL as part of this landslide study, and the details are presented in Appendix A. The approximate locations of the landslides and observations identified from the API are presented in Figure 2. A summary of the key observations from the API is given below.

Whilst sections of Shatin Pass Road are visible in the earliest available aerial photographs (1949), both slope No. 11NE-A/C284 and the section of Shatin Pass Road located directly below are just outside the coverage of the aerial photographs. The subject slope is first visible in the 1963 aerial photograph. Based on the API, no significant changes to the road alignment or evidence of upgrading work were observed up to 2001.

Based on the 1963 aerial photographs, a number of structurally controlled instabilities were observed in the vicinity of the subject slope. Two landslide scars (i.e. 63A and 63B on Figure 2), both approximately 12 m long and 4 m wide, were observed on the natural hillside above the crest of the western end of slope No. 11NE-A/C284. These failures are interpreted as sliding failures probably along distinctive discontinuities and might have occurred during the construction of Shatin Pass Road. Four minor scars (i.e. 63C, 63D, 63E and 63F on Figure 2) were also observed (all estimated to be between 1 m^3 and 3 m^3 in volume) along the unlined ditch above the crest of the subject slope. A local shallow depression was observed on the natural hillside directly above the crest of the cut slope at the location of the May 2002 rockfall (Figure 2).

Above the crest of the eastern end of the subject slope, a curved lineament of approximately 25 m long was identified at midway between the slope crest and the unlined ditch. This photolineament was investigated in the post-failure ground investigation under

HCL's supervision. Details are given in Section 8.

A landslide scar approximately 12 m long and 7 m wide, located at the crest of slope No. 11NE-A/C281 immediately to the east of the subject slope, was observed in the 1973 aerial photographs.

A minor failure (with an estimated volume of <5 m^3) was observed at the crest of slope No. 11NE-A/C284, about 5 m to the west of the May 2002 rockfall, in the 1999 low-level (4000') aerial photographs. There is no record of this failure in the GEO Landslide Database. A series of possible seepage points, observed on the aerial photographs as dark toned streaks on the road surface, are visible at three locations below the subject slope. As described in detail in Appendix A, seepage was recorded at one or more of these locations in the majority of aerial photographs (from 1963 to 1999) reviewed. The seepage points are labelled as Seepage Points 1, 2 and 3 on Figure 2. Seepage from these locations could still be observed during HCL's inspections following the May 2002 rockfall (see Section 10).

6. PREVIOUS ASSESSMENTS

In 1995, slope No. 11NE-A/C284 was assigned by the Systematic Inspection of Features in the Territory (SIFT) project as a SIFT Class 'C1' feature, i.e. "....formed or substantially modified before 30.6.78".

On 27 September 1996, an inspection under the Systematic Identification and Registration of Slopes in the Territory (SIRST) project was carried out for the subject slope. The inspection recorded no signs of distress but "heavy seepage from isolated rock joints". The rock blocks involved in the May 2002 rockfall were indicated as a "loose block" on a photograph taken during the inspection (see Plate 6). The condition of the slope face was assessed as being "Fair". It was recommended in the SIRST inspection record that an Engineer Inspection (EI) should be carried out for the subject slope. According to the SIS, the consequence-to-life category of slope No. 11NE-A/C284 is "3" and the corresponding CNPCS score is 2.9.

7. MAINTENANCE INSPECTIONS

In May 2001, Maunsell Geotechnical Services Ltd. (MGSL) carried out an Engineer Inspection (EI) for slope No. 11NE-A/C284 under a consultancy agreement with the HyD. The inspection recorded that loose blocks were identified at some locations on the slope surface and loose rock debris was observed to have accumulated at the slope toe, behind the existing wire mesh netting at the western portion of the slope [probably installed by HyD following the April 2000 rockfall incident, see Section 4.1]. Also, seepage was observed at some areas near the slope toe during the inspection. A close-up photograph attached to the EI report noted that there was an "open joint" at the eastern portion of the slope. The "loose block" identified in 1996 SIRST inspection and subsequently involved in the May 2002 rockfall incident was located above this joint. The EI report noted the occurrence of the 2000 rockfall incident (i.e. GEO Incident No. K2000/4/4) and no other signs of instability. The overall state of slope maintenance was classified as "Fair".

As indicated in the "Record of Slope and Retaining Wall" attached to the EI report, reference was made to a memo dated 10 April 2000 issued by the GEO District Division to HyD regarding the 2000 rockfall, which noted that "Landslide and/or other movement has continuously been occurring in the slopes along Shatin Pass Road and Jat's Incline. This indicates that these slopes involve complex geological and groundwater conditions". Also, a patch of the shotcrete of 3 m by 4 m was observed near the slope crest in the vicinity of the May 2002 rockfall as shown in the Record Photograph V5 (reproduced as Plate 7) in the EI report.

Following the inspection, maintenance works comprising the provision of wire mesh netting for the exposed rock surface over the central and eastern portions of the slope, removal of loose rock debris at the slope toe, sealing up of open joints in the rock slope and provision of local surfacing to prevent ingress of water were recommended by MGSL to HyD in November 2001. According to HyD, the maintenance works recommended by MGSL was "not an urgent recommendation" and they "planned to carry out the works recommended by MGSL together with the annual routine maintenance works for the slope". The maintenance works recommended by MGSL and the annual routine maintenance works for 2002 had not been carried out at the time of the incident. In addition, the EI report recommended that a "Low Priority Stability Assessment" be carried out for the slope. HyD noted that the slope "has consequence category of 3 (i.e. negligible consequence)" and the "Low Priority Stability Assessment" had not been implemented at the time of the May 2002 rockfall incident.

On 4 August 2001, a Routine Maintenance Inspection (RMI) was carried out for slope No. 11NE-A/C284 by HyD. Routine maintenance works comprising removal of surface debris and unplanned vegetation and clearance of drainage channels were recommended. A Works Order was issued on 31 October 2001 by HyD for the recommended routine maintenance works. The toe channel was clear and no overgrown vegetation was observed during the inspection by HCL in May 2002.

8. GROUND INVESTIGATION

Four shallow inspection trenches, each about 0.5 m depth, together with limited vegetation clearance, were carried out to study the 25 m long curved lineament between the unlined ditch on the natural hillside and the crest of the slope, which is identified in the 1963 aerial photographs. The inspection trenches were located across the lineament and the approximately locations are shown in Figure 2. The natural hillside in the vicinity of the lineament is sparsely vegetated and the slope angle is about 50º to 70º. The lineament forms a prominent break in slope across the hillside (Plate 5). Two inspection trenches on the eastern end of the lineament exposed colluvial material comprising loose to medium dense, dry, yellowish brown, silty sand with many sub-angular cobbles and gravel of moderately decomposed granite and quartz fragments. The two trenches at locations above Seepage Point 2 (Figure 2) across the lineament exposed moderately strong, dry, dark yellowish brown moderately decomposed granite with very closely spaced, narrow and sediment infilled (with loose yellowish brown silty sand) joints. Topsoil, exposed in the top 0.1 m to 0.2 m of all the trenches, is loose, dark grey organic silty clayey sand with some angular cobbles of moderately decomposed granite with many fine roots throughout, as shown in Plates 8 and 9. The above observations suggest that the lineament is probably an abandoned access path

instead of a tension crack.

9. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauge (No. K07) to slope No. 11NE-A/C284 is located at Tsz Ching Estate, about 450 m southwest of the subject slope (Figure 4). The daily rainfall records of raingauge No. K07 are presented in Figure 5, which reveal that within the 7 days preceding the May 2002 rockfall incident, about 147.5 mm of rainfall was recorded. On the day of the landslide (i.e. 22 May 2002), about 14 mm rainfall was recorded by raingauge No. K07 before the occurrence of the incident at about 8:30 p.m. The highest daily rainfall within the 7 days preceding the May 2002 rockfall was 71 mm on 19 May 2002 (i.e. 3 days before the incident). Based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994), the return period of the daily rainfall on 19 May 2002 is about one year.

For the rockfall incident that occurred in 2000 on the subject slope, a similar rainfall analysis was carried out for the daily rainfall records of raingauge No. K07. Although there are no records on the exact time of failure, it is considered that the date of failure should be the same as the date of reporting (i.e. about 11:30 a.m. on 6 April 2000) taking into consideration that the volume of traffic using the road would not be very low and the incident was probably reported to Government not long after the failure. Over the 15 days prior to 6 April 2000, the only significant rainfall was on 3 April 2000 with daily rainfall of about 111 mm (Figure 6). The return period of the daily rainfall on 3 April 2000, based on Lam & Leung (1994), is about one year.

10. POST-FAILURE OBSERVATIONS OF THE ROCKFALL SITE

HCL inspected the site on a number of occasions between 24 May 2002 and 3 July 2002. The source of the rockfall was located at about 7 m to 8 m above the toe of slope No. 11NE-A/C284 (Figures 7 and 8). As indicated in photographs taken before and after the May 2002 rockfall incident by the SIRST inspection team and HCL respectively (Plates 6 and 10), the primary source of the failure was a series of rock blocks located close to the crest of the cut slope. After detachment of the series of rock blocks originating from the primary source, the debris appears to have dislodged some other thin slab-like rock blocks located below and to the east of the primary source, resulting in a minor secondary failure (Figure 7 and Plate 2). The total volume of the rock blocks and debris is about 7 m^3.

The rockfall debris came to rest on Shatin Pass Road, close to a concrete bridge over a natural drainage line at the eastern end of the slope. Debris from the rockfall completely blocked Shatin Pass Road. No casualties were reported. The debris had been removed and the road reopened at the time of inspection by HCL on 24 May 2002.

The height of the rock slope at the location of the failure was about 8 m (Figure 8), with the upper portion of the slope inclined at angles of about 64º to 68º and the lower portion inclined at angles of about 80º to 90º. The slope was cut into strong, light pinkish grey, moderately to slightly decomposed, medium-grained granite with generally closely spaced joints. The basal release joint plane beneath the detached rock blocks was inclined at angles

of about 64º to 68º out of the slope, which is probably a sheeting joint. The surface of the joint was planar, stepped and with a lateral persistence of about 10 m (Figures 7 & 8 and Plate 11). The sheeting joint extends beneath a series of potentially unstable rock blocks with an approximate volume of 30 m^3 located at the far eastern end of the slope (Plates 12 to 14). A sub-vertical joint set with a typical orientation of 70º-90º/240º-260º was observed at the eastern portion of the back scarp (Plate 11). The site inspection by HCL revealed that part of the "open joint" (see Section 7) recorded in the MGSL's EI report could still be observed at the eastern portion of the back scarp (Plates 10 and 13). The nature of this "open joint" is unusual and the possible modes of formation include concentrated subsurface flow within the sheeting joint, washout of a mineral infill or mineralised vein, or prolonged movement along the joint.

An accumulation of cobbles and boulders in a soil matrix comprising dark brown silty sand and many shrub roots were exposed at the upper portion of the back scarp of the May 2002 rockfall (Plate 10). The confinement to the soil matrix was removed following the May 2002 rockfall. A moderately strong seepage with a flow rate of about 1 litre/minute and 2 litre/minute was observed from the base of the soil matrix (Plate 2) on 24 May 2002 and on 30 May 2002 respectively. It is noted that the rainfall recorded by raingauge No. K07 between the two visits was about 3 mm.

A scan-line survey was carried out by HCL for the whole length of the subject slope. Furthermore, a more detailed rock joint mapping was carried out in the vicinity of the May 2002 rockfall location, which covers the eastern-most 30 m of the slope. Stereoplots of rock joint data collected from the scan-line survey and the rock joint mapping are presented in Figures 9 and 10 respectively. It is noted from the stereoplots that there is generally little variation in the distribution of joint orientations along the subject slope. The adversely orientated joints forming the basal release (sliding) surface of the recent failure is shown in Figure 9. Although similar orientated joints were identified occasionally at various locations along the subject slope (Figure 10), they were limited in persistence and would not form a pervasive joint set within the rock mass. Based on the kinematic analysis of the rock joints, it is possible that toppling and wedge failure modes could occur on the subject slope (Figures 9 and 10). As shown in Plate 15, the joint set for potential toppling is well developed at the central portion of the subject slope.

The drainage line to the east of the location of the recent rockfall is interpreted as a fault on the published geological map of the site (Figure 3). The field inspection by HCL found evidence of possible faulting within the exposed rock forming the bed of the drainage line, viz. a series of 50 mm to 100 mm thick quartz veins within a 0.5 m to 1.0 m wide shear zone. The zone affected by the possible faulting is less than 1 m wide and does not appear to affect slopes Nos. 11NE-A/C284 and 11NE-A/C281. No obvious signs of intrusion of dykes could be observed on these slopes. The spacing of sub-vertical joints was noted to decrease towards the location of the drainage line.

Site observation by HCL in May 2002 revealed that the wire mesh netting at the western portion of the slope (Figure 2) was hanging loosely in places over the rock surface. The fixing of the wire mesh is different from that presented in CED Standard Drawing No. C2205A. Two loose blocks of approximately 0.7 m wide each were observed over the upper half of the central portion of the slope (Plate 15). At the central and eastern portions of the slope, several sub-vertical joints dipping into the slope were observed near the slope toe,

which are liable to induce toppling failures. Weak to moderately strong seepage was observed at Seepage Points 1, 2 and 3 as shown in Figure 2, where seepage had been frequently observed in the aerial photograph interpretation.

Inspection of the adjacent cut slope No. 11NE-A/C285, which is located to the west of the subject slope, revealed that there is an area of overhanging and potentially unstable blocks as shown in Figure 2 and Plate 16. To the east of the subject slope is slope No. 11NE-A/C281 and a potentially unstable rock block about 0.7 m wide at about 4 m from the slope toe was identified (Figure 2 and Plate 17). The sub-vertical joint forming the rear release surface of this block was opened by between 20 mm and 30 mm. Also, a cluster of potentially unstable rock blocks was identified at the crest of slope No. 11NE-A/C281 (Figure 2 and Plate 18).

11. DIAGNOSIS OF THE PROBABLE CAUSES OF THE FAILURE

The primary source of the failure was a series of rock blocks located close to the crest of the cut slope (Plate 7). After detachment of the series of rock blocks originating from the primary source of failure, the debris appears to have dislodged some other thin slab-like rock blocks located below and to the east of the primary source, resulting in a minor secondary failure. The incident involved a planar sliding failure along an adversely orientated steeply dipping basal release surface, which is probably a sheeting joint. The joint dips at about 64º to 68º out of the slope and is laterally persistent for about 10 m (Plate 2 and Figures 7 and 8). The detachment of rock blocks in May 2002 may have been the result of progressive deterioration of the rock slope, as indicated by the opening up of the sheeting joint probably due to past movement and washout of a mineral infill or a mineralised vein. Root action associated with unplanned vegetation would also have been a contributory factor to the rockfall incident.

It is noted that 14 mm of rainfall was recorded in two days preceding the May 2002 rockfall (Figure 5). However, the highest daily rainfall was 71 mm on 19 May 2002 (i.e. 3 days before the incident). The flow rate of seepage observed by HCL from the pocket of cobbles and boulders exposed at the crest of the back scarp, was about 1 litre/min on 24 May 2002 and about 2 litres/min on 30 May 2002. The total rainfall recorded over this period is about 3 mm. It is possible that there may have been a delayed response of the subsurface groundwater flow and the build-up of a transient cleft water pressure behind the "loose block", which may be a contributory factor of the May 2002 rockfall incident. The rainfall preceding the rockfall was not particularly heavy and the corresponding return period was about one year.

12. DISCUSSION

Based on the API, slope No. 11NE-A/C284 was formed before 1949. The adversely orientated sheeting joint identified following the May 2002 rockfall extends beneath a series of potentially unstable rock blocks, with an approximate volume of 30 m^3, located at the far eastern end of the slope (Plate 14). Failure of these rock blocks could potentially result in some damage to the reinforced concrete bridge below. Also, the pocket of cobbles and boulders in a sandy matrix at the crest of the back scarp exposed by the May 2002 rockfall is

potentially unstable, given that it is seated on steeply inclined ground above the exposed portion of the sheeting joint and moderately strong seepage was observed to be emerging from its base.

Along the central and eastern portions of the subject slope, there are adversely orientated joints with a potential toppling failure mode (see Plate 15). Two loose blocks of approximately 0.7 m wide were observed at the central portion of the slope (Plate 15). Given progressive deterioration, the loose blocks and the adversely orientated rock blocks may become more vulnerable to rain-induced failures. At the time of HCL's inspection in May 2002, no signs of an incipient major failure on slope No. 11NE-A/C284 were observed.

Inspection of adjacent slopes Nos. 11NE-A/C285 and 11NE-A/C281 also revealed that there are some potentially unstable rock blocks on these slopes (Plates 16 to 18).

Based on the GEO's landslide database, a total of 16 landslide incidents were recorded on cut slopes along Shatin Pass Road between 1986 and 2001. Including the May 2002 rockfall, there have been three rockfall failures on slopes along and in the vicinity of Shatin Pass Road in 2002. This indicates that slopes along Shatin Pass Road have high susceptibility to failures.

The 25 m curved lineament as identified in the 1963 aerial photographs was inferred as a possible tension crack based on API. Ground truthing and ground investigation, consisting of vegetation clearance and the excavation of shallow inspections trenches, were carried out to verify the actual origin of the curved lineament. The findings of ground investigation and detailed site inspection suggest that the curved lineament is probably an abandoned access path instead of a tension crack. This demonstrates the importance of using ground investigation to corroborate the findings of API.

13. CONCLUSIONS

It is concluded that the May 2002 rockfall involved a planar sliding failure of a loose block along an adversely orientated steeply dipping basal release surface. This basal plane is probably a sheeting joint that is laterally persistent for about 10 m across the eastern end of the slope. The detachment of rock blocks may have been the result of progressive deterioration of the rock slope, as indicated by the gradual dilation and opening up of the sheeting joint probably due to past intermittent movement and progressive washout or erosion of a mineral infill or a mineralised vein. Root action associated with unplanned vegetation would also have been a contributory factor to the rockfall.

The rockfall was likely to be triggered by rainfall. However, the highest significant daily rainfall of 71 mm, recorded 3 days before the May 2002 rockfall, was not particularly heavy with an estimated return period of about one year. It is possible that there may have been a delayed response of the subsurface groundwater flow and build-up of a transient cleft water pressure behind the "loose block", which triggered the May 2002 rockfall incident.

The EI report prepared by MGSL in November 2001 for slope No. 11NE-A/C284 indicated that loose blocks, open joints and seepage were observed on the slope. An "open joint" referred to in the EI report was the sheeting joint beneath the "loose block" identified in

inspection by SIRST consultants in 1996 and involved in May 2002 rockfall incident. Slope protective measures comprising provision of wire mesh netting and sealing up of open joints were recommended by MGSL to HyD in November 2001. No specific works were recommended by the EI for the "loose block" that subsequently failed in May 2002. There were also no specific indications in the EI report on which rock joints were to be sealed-up. The recommended maintenance works were yet to be carried out at the time of the May 2002 rockfall incident.

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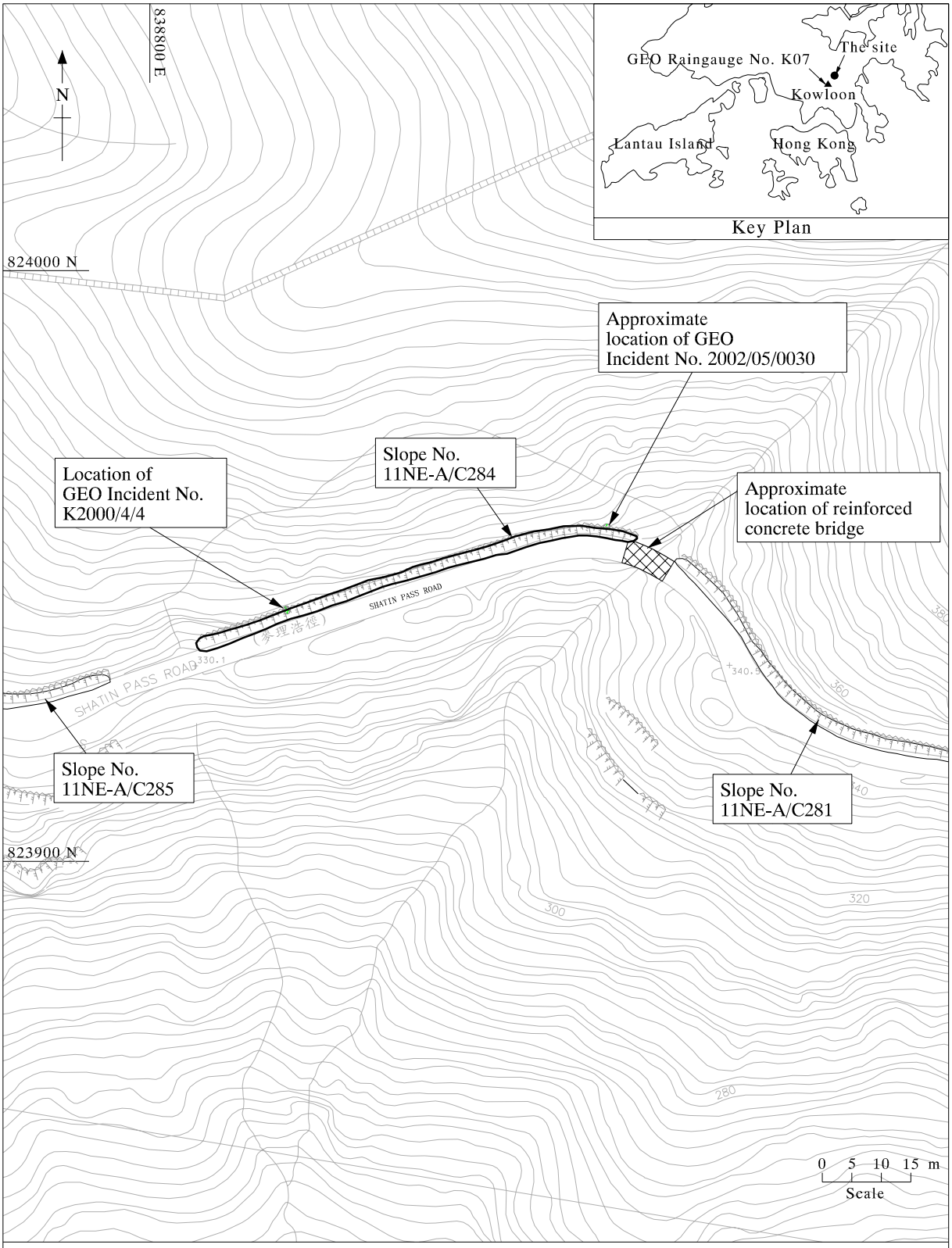

Figure 1 - Site Location Plan

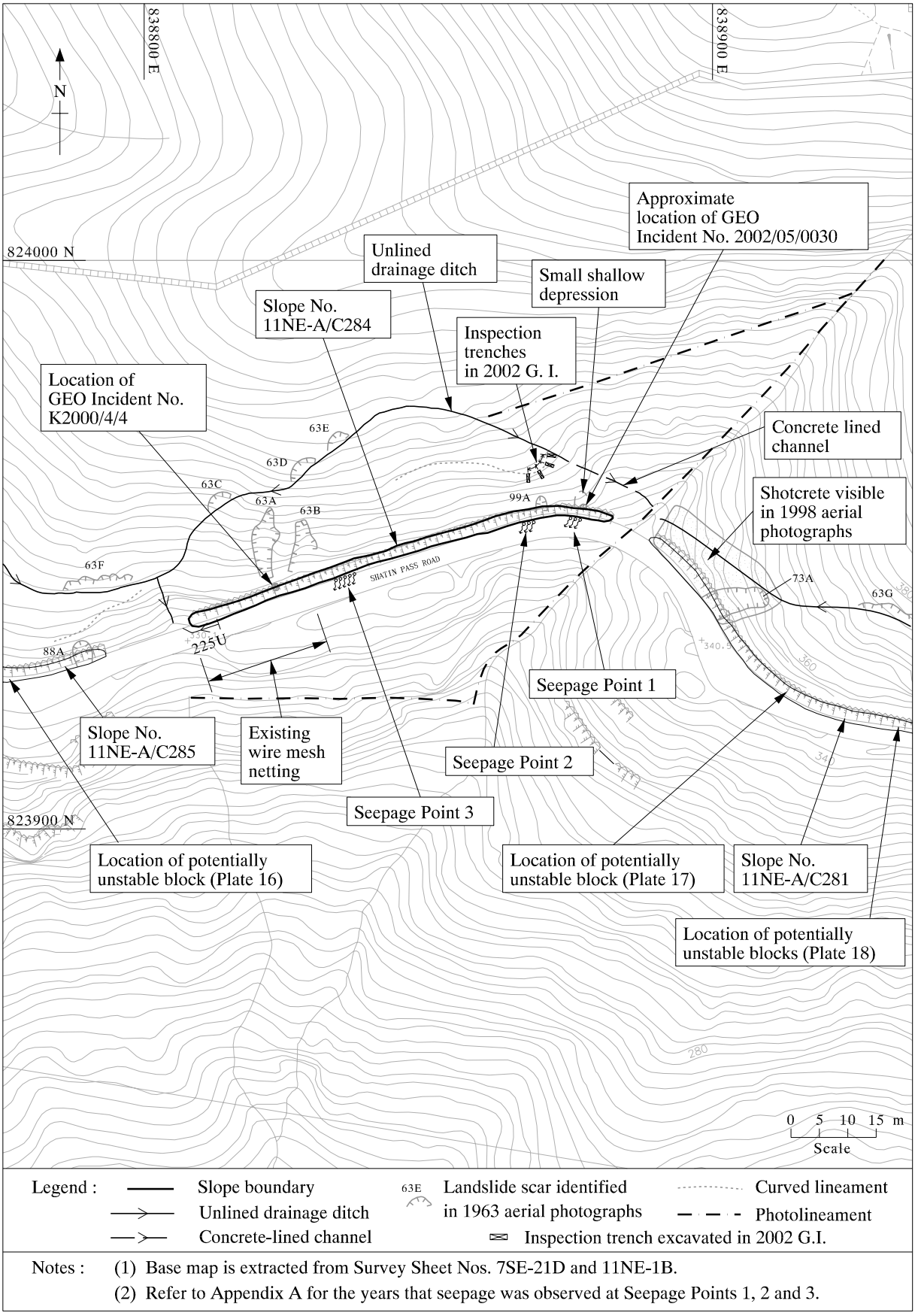

Figure 2 - Site Layout Plan and Key Observations

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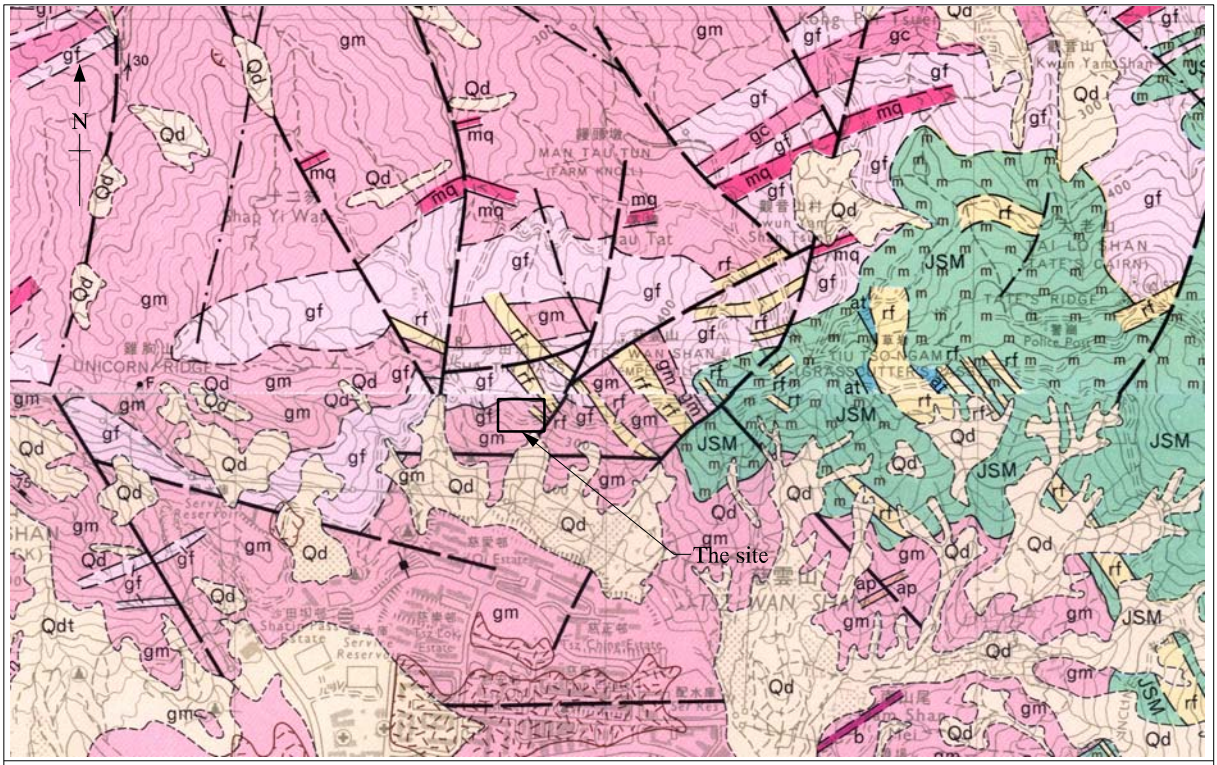

Legend :

Quaternary Deposits (Onshore)

Qd	Debris flow deposits

Solid Geology

JSM	Fine ash to coarse ash tuffs, tuff-breccia and tuffite
gf	Fine-grained granite
gm	Medium-grained granite
gc	Coarse-grained granite
mq	Quartz monzonite
rf	Feldsparphyric rhyolite
ap	Aplite

Geological Lines

– – – – –	Geological Boundary, Superficial Deposits
———–*–	Geological Boundary, Solid Rock
—|—*—	Faults (cross indicates downthrow side)
— - — - -	Photogeological Lineament

* Broken lines on map face denote uncertainty

Note : Extract from Sheets 7 and 11 of Hong Hong Geological Survey (Scale 1:20 000) Map Series HGM20.

Figure 3 - Solid and Superficial Geology of the Landslide Site

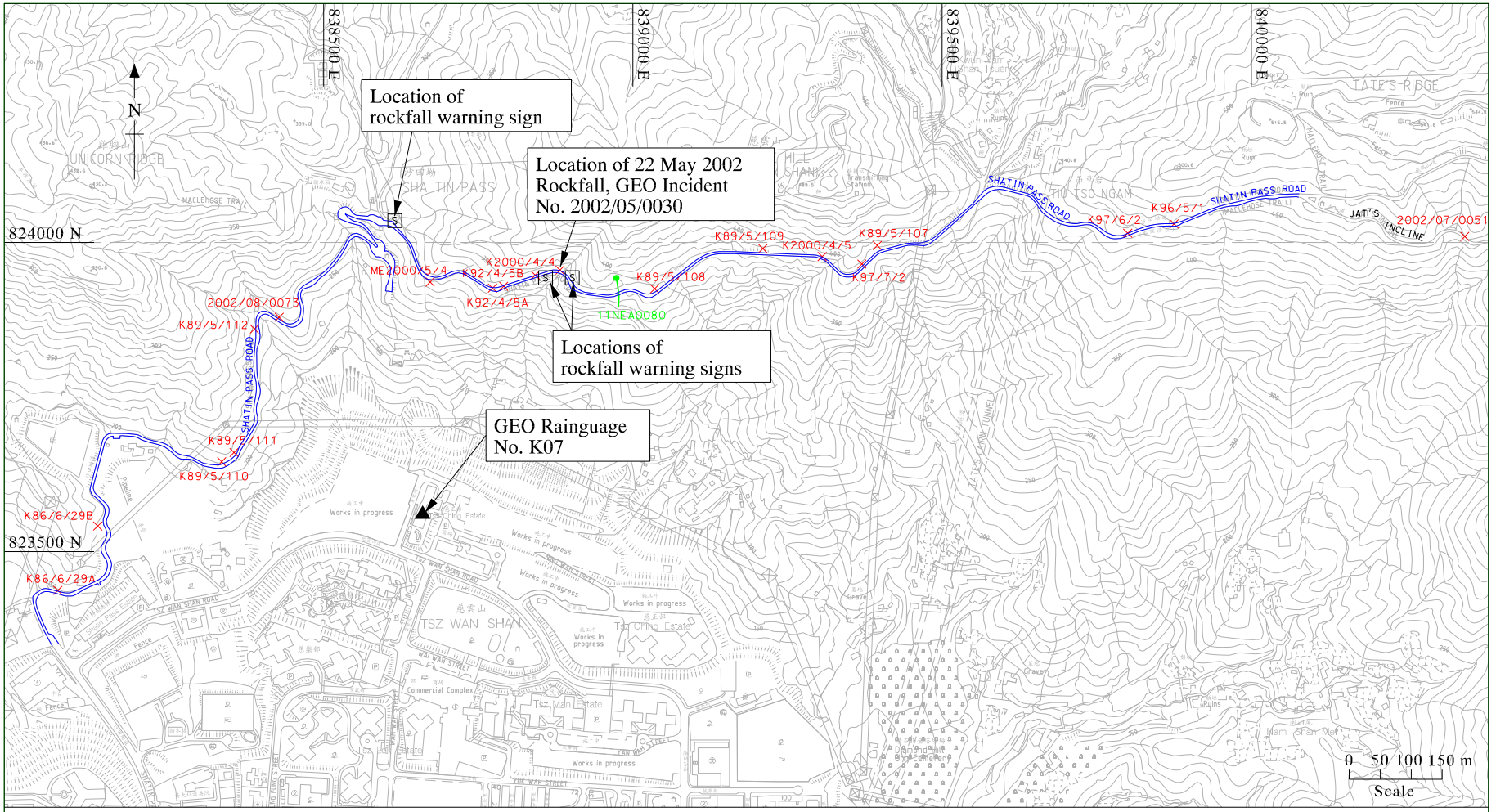

Figure 4 - Locations of Recorded Landslides along Shatin Pass Road

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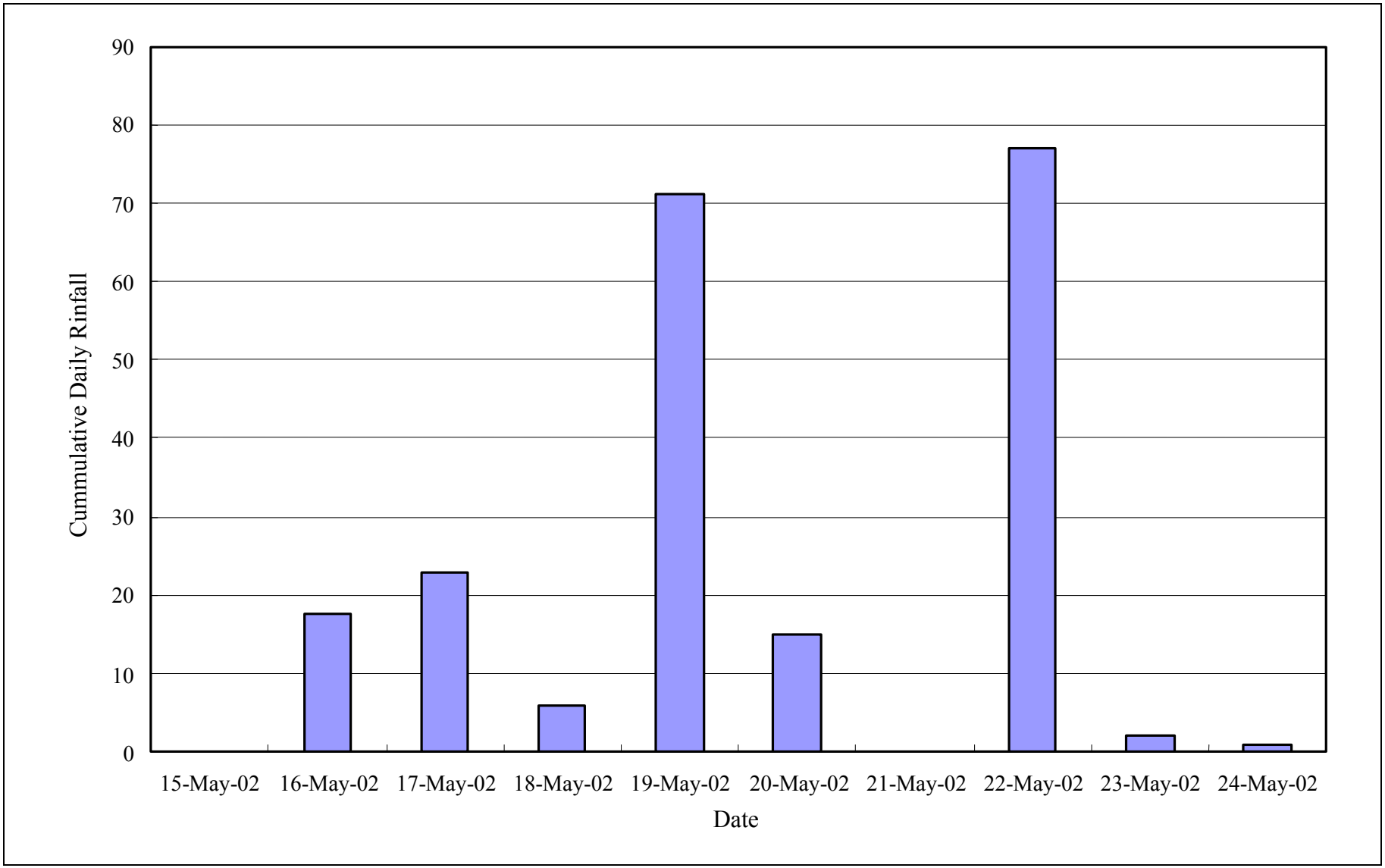

Figure 5 - Daily Rainfall Summary for Raingauge No. K07 in 2002

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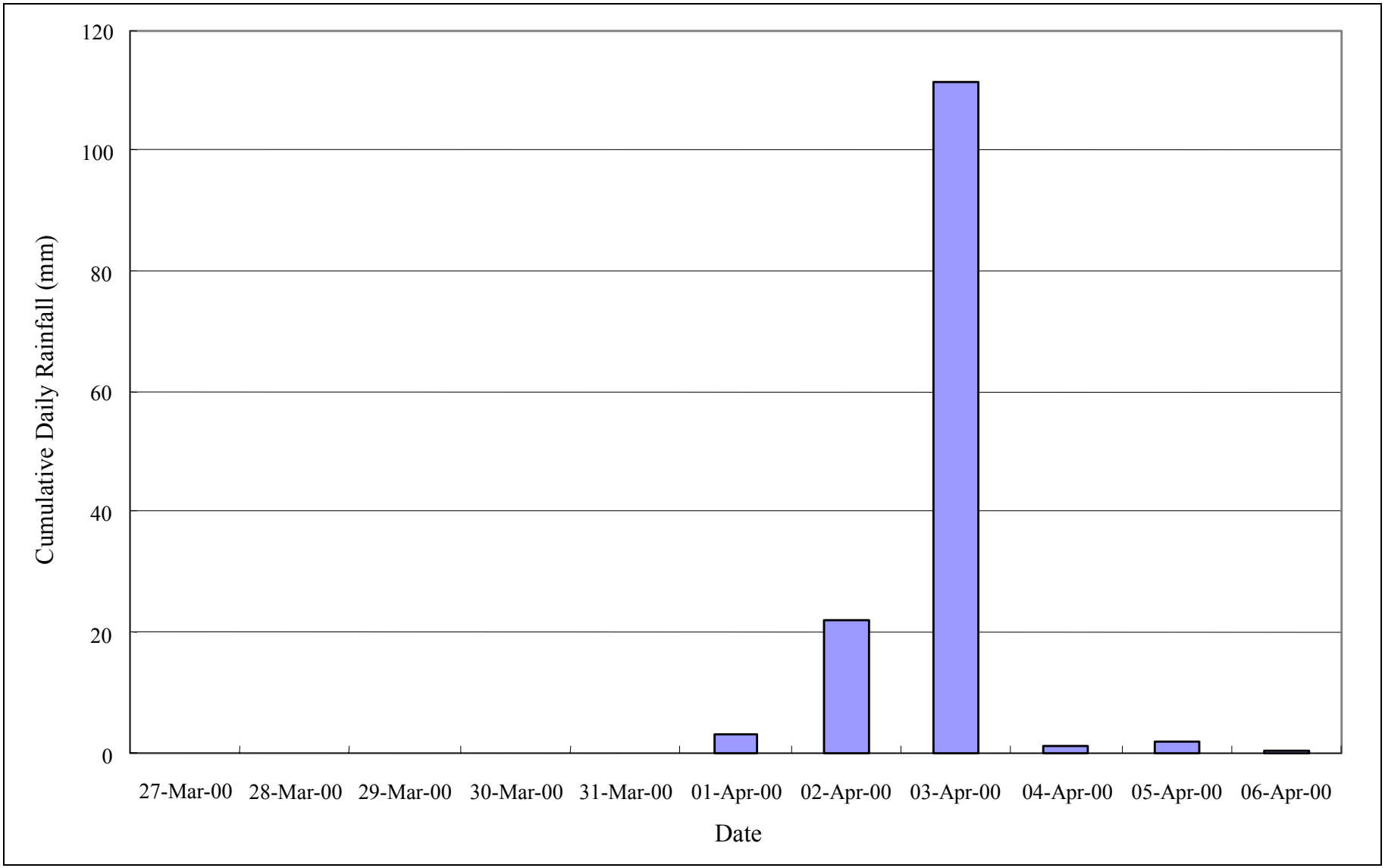

Figure 6 - Daily Rainfall Summary for Raingauge No. K07 in 2000

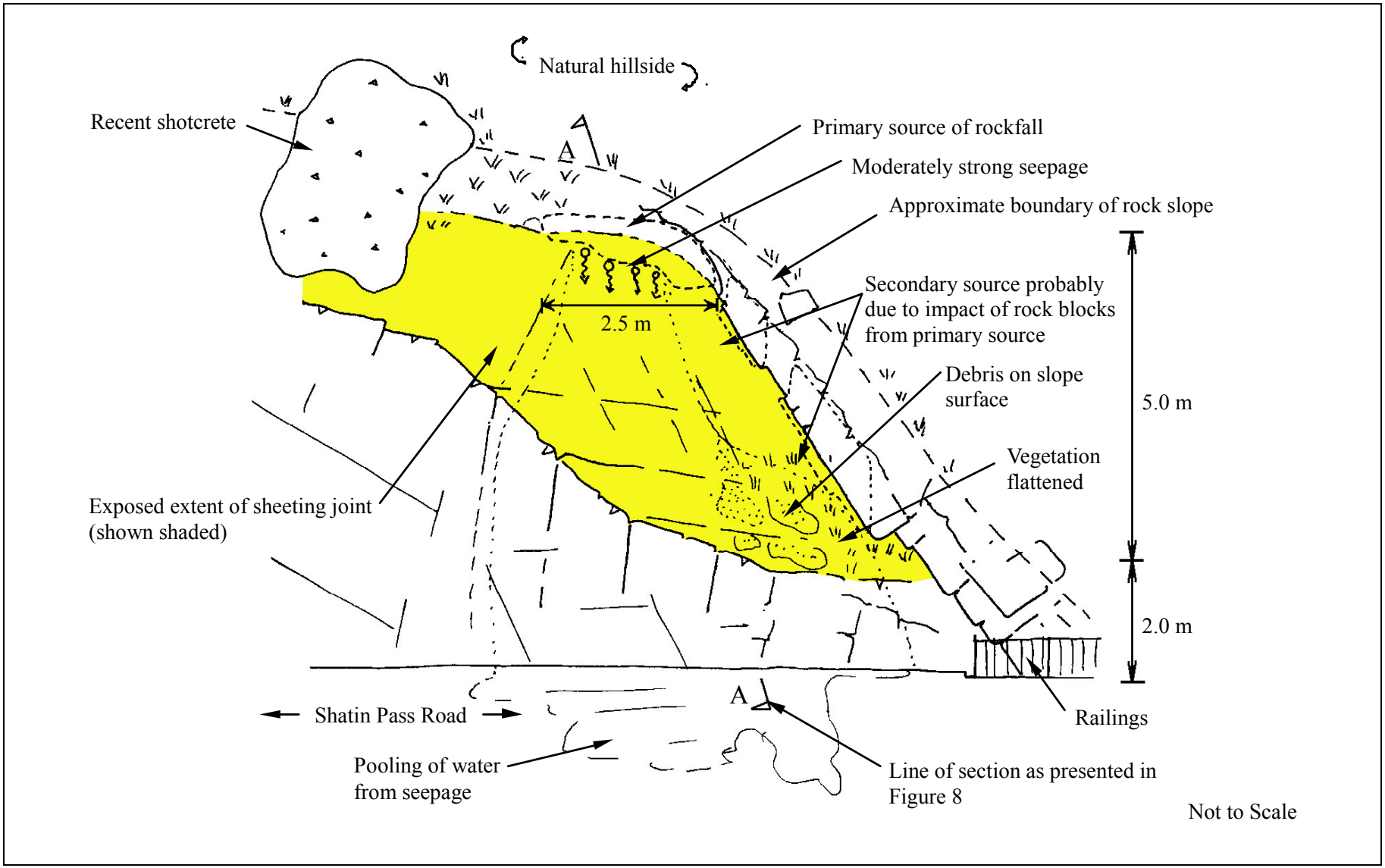

Figure 7 - Front Elevation of Slope No. 11NE-A/C284 at the 22 May 2002 Rockfall Location

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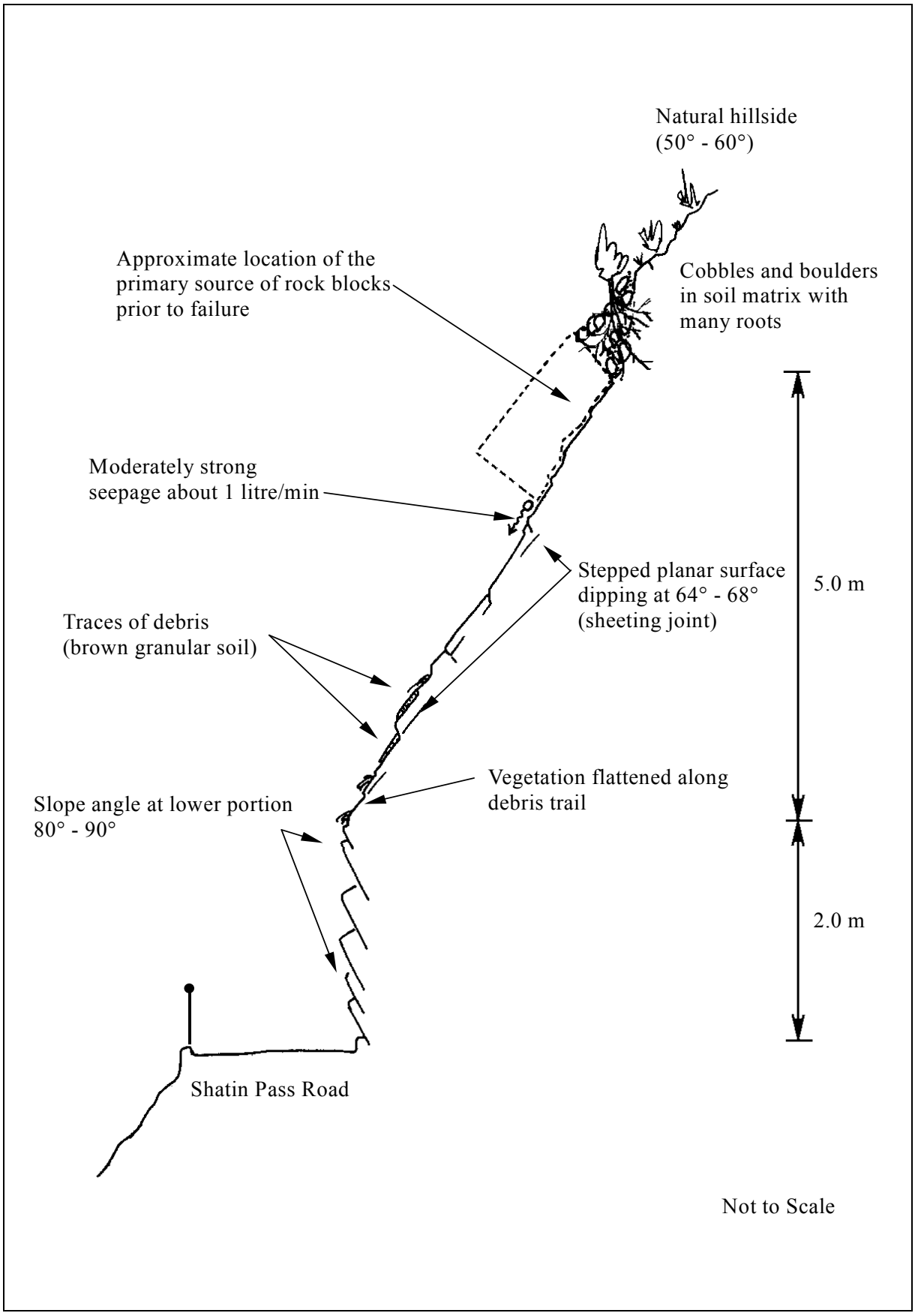
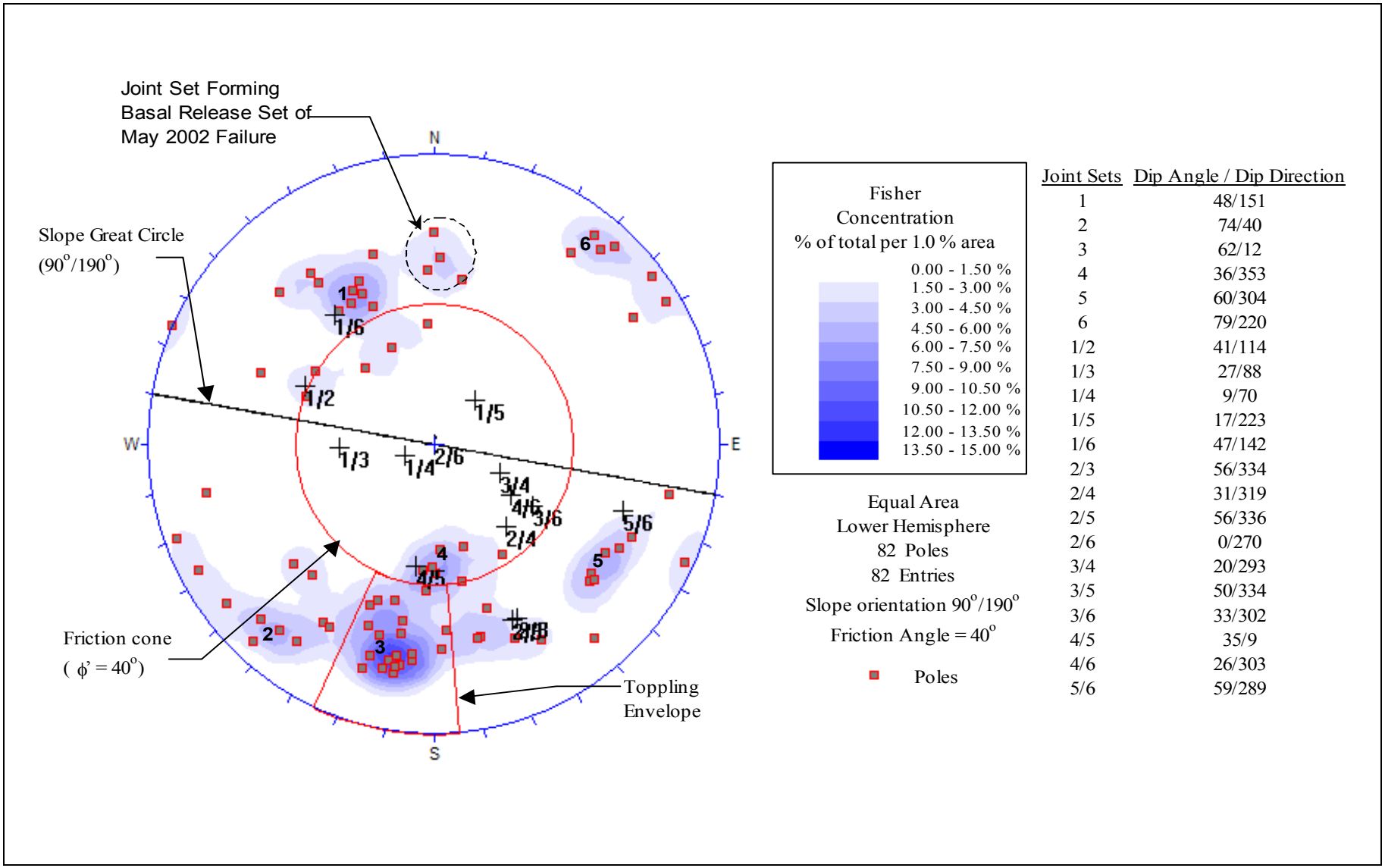
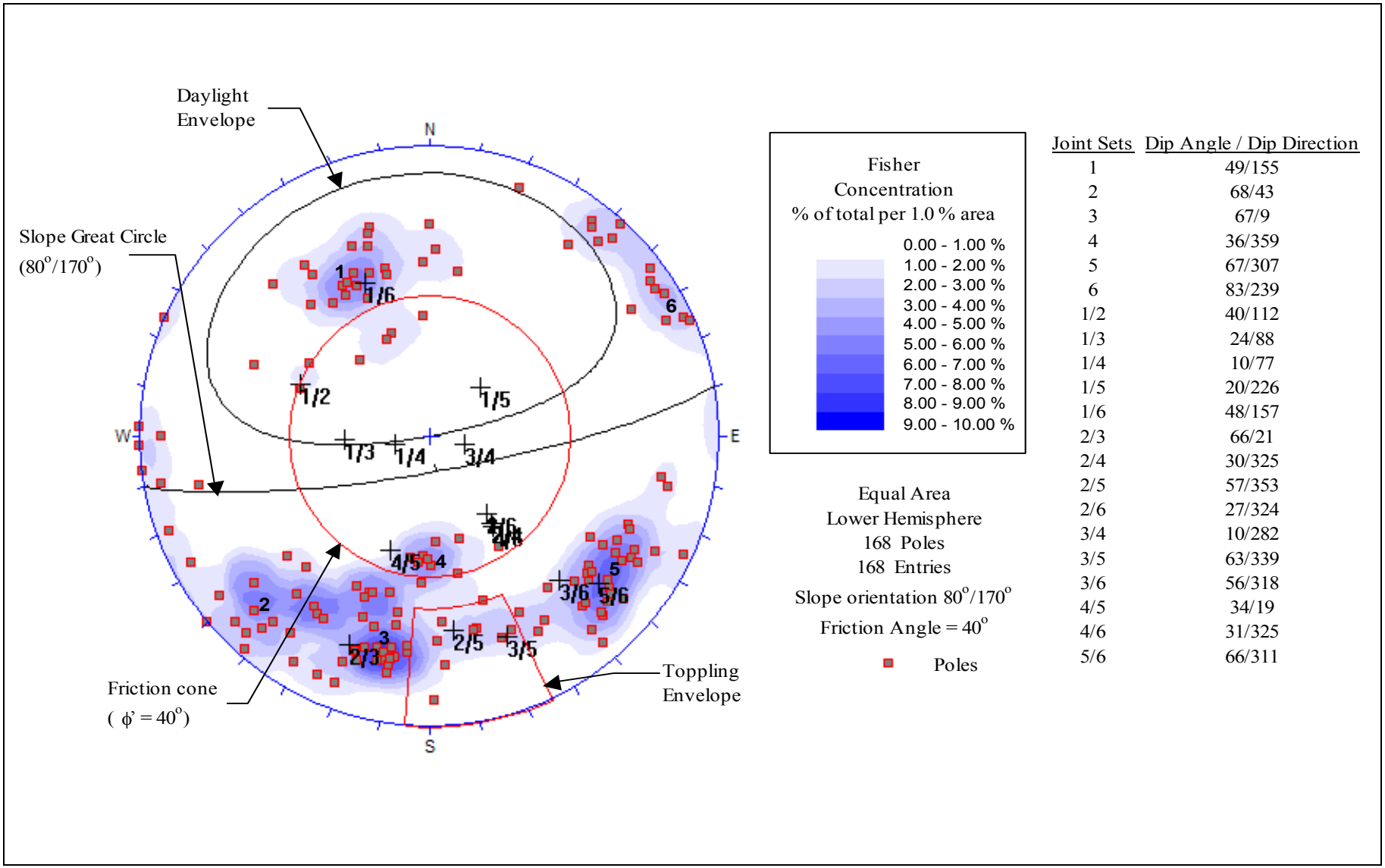


Figure 8 - Section A-A of the 22 May 2002 Rockfall



Joint Sets	Dip Angle / Dip Direction
1	48/151
2	74/40
3	62/12
4	36/353
5	60/304
6	79/220
1/2	41/114
1/3	27/88
1/4	9/70
1/5	17/223
1/6	47/142
2/3	56/334
2/4	31/319
2/5	56/336
2/6	0/270
3/4	20/293
3/5	50/334
3/6	33/302
4/5	35/9
4/6	26/303
5/6	59/289

Figure 9 - Stereoplot of Joint Orientations from Detailed Mapping Near the May 2002 Rockfall



Joint Sets	Dip Angle / Dip Direction
1	49/155
2	68/43
3	67/9
4	36/359
5	67/307
6	83/239
1/2	40/112
1/3	24/88
1/4	10/77
1/5	20/226
1/6	48/157
2/3	66/21
2/4	30/325
2/5	57/353
2/6	27/324
3/4	10/282
3/5	63/339
3/6	56/318
4/5	34/19
4/6	31/325
5/6	66/311

Figure 10 - Stereoplot of Joint Orientations for the Whole of Slope No. 11NE-A/C284

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Plate 1 - General View of the 22 May 2002 Rockfall (Photograph taken on 23 May 2002 by GEO)

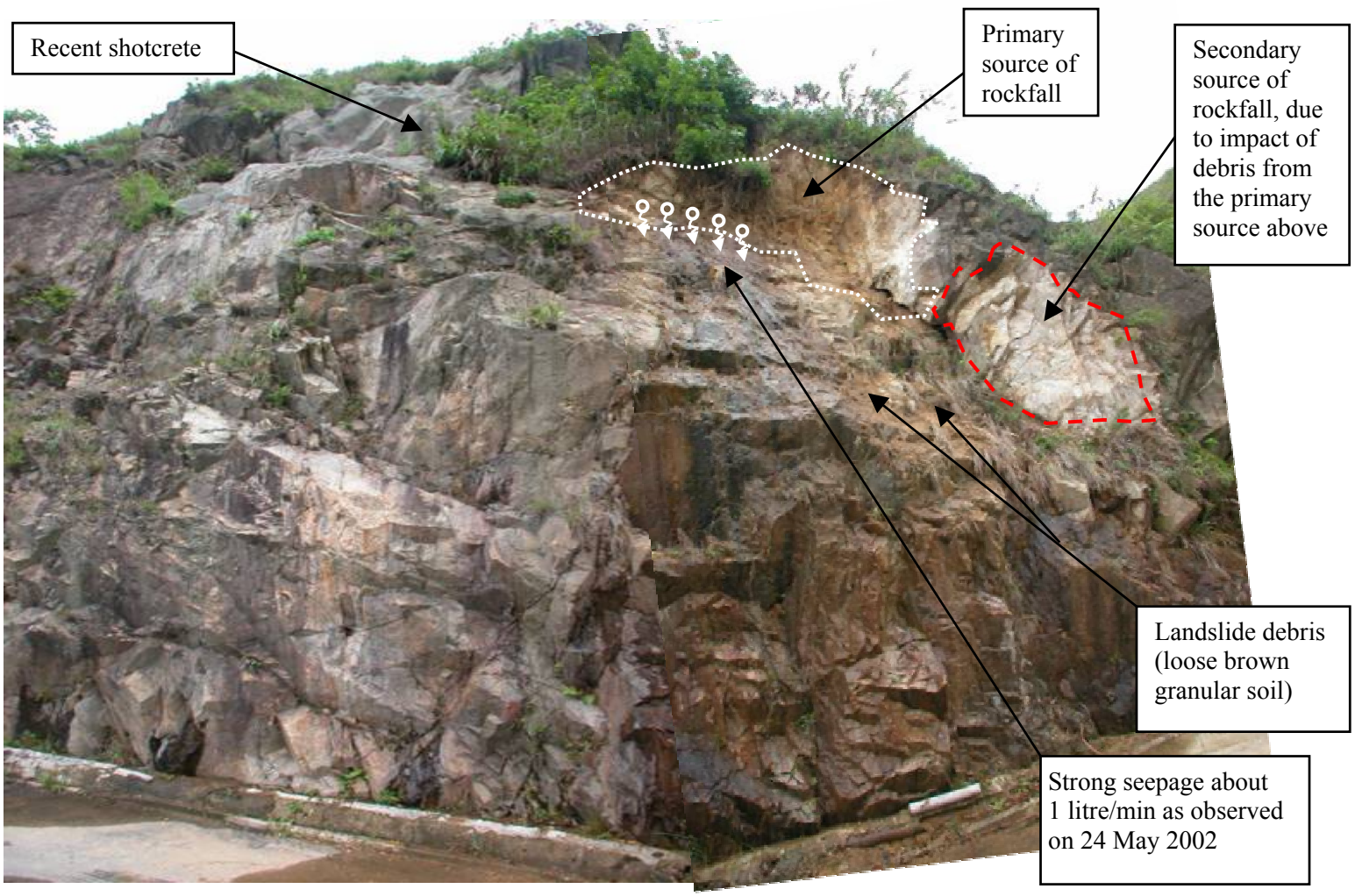

Plate 2 - General View of the Source of the Rockfall (Photograph taken on 24 May 2002 by HCL)

Plate 3 - General View of Landslide Debris Deposited on Shatin Pass Road
(Photograph taken on 23 May 2002 by GEO)

Plate 4 - View of the Western Portion of Slope No. 11NE-A/C284
(Photograph taken on 24 May 2002 by HCL)

Plate 5 - View of the Eastern Portion of Slope No. 11NE-A/C284 (Photograph taken on 3 July 2002 by HCL)

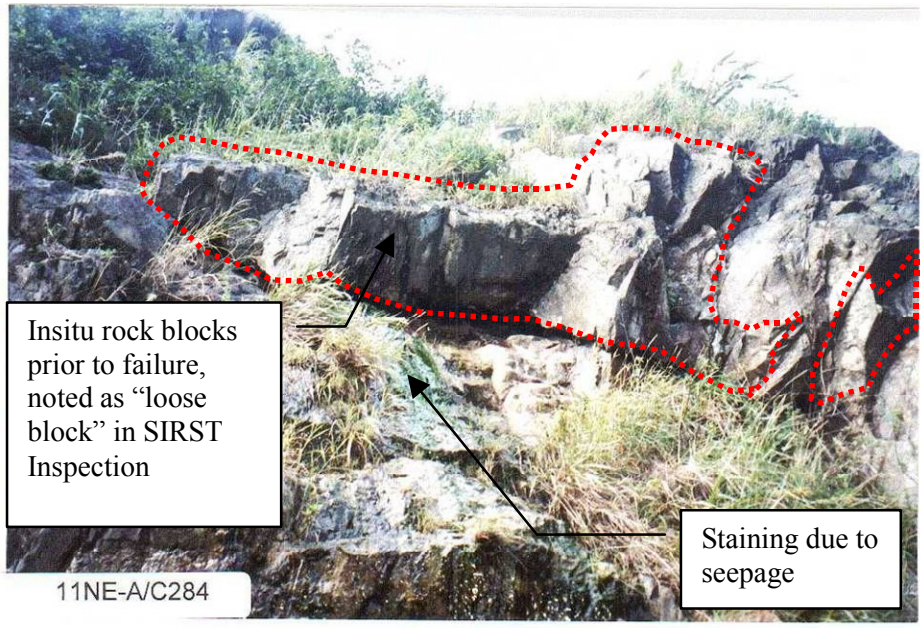

Plate 6 - View of the Location of the May 2002 Rockfall in 1996
(Photograph taken on 26 September 1996 during SIRST Inspection)

Plate 7 - General View of the Eastern End of Slope No. 11NE-A/C284
(Photograph taken on 11 May 2001 during MGSL Inspection)

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Plate 8 - View of the Curved Lineament Located Above Slope No. 11NE-A/C284 (Photograph taken on 14 June 2002 by HCL)

Plate 9 - Inspection Trench Across Curved Lineament Showing Exposed Rock on Side and Base of Trench (Photograph taken on 17 June 2002 by HCL)

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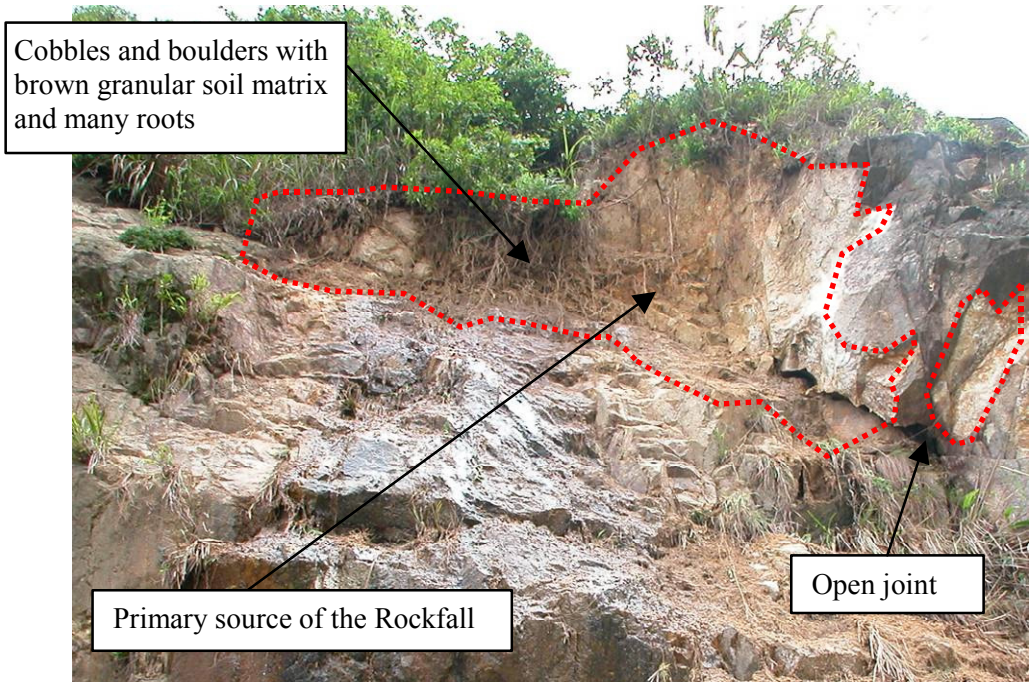

Plate 10 - View of the Source of the Rockfall (Photograph taken on 24 May 2002 by HCL)

Plate 11 - View of the Source of the Rockfall Showing the Orientations of Principal Release Surfaces (Photograph taken on 24 May 2002 by HCL)

Plate 12 - Detailed View of an Open Joint Daylighting Below a Series of Large Potentially Unstable Blocks (Photograph taken on 14 June 2002 by HCL)

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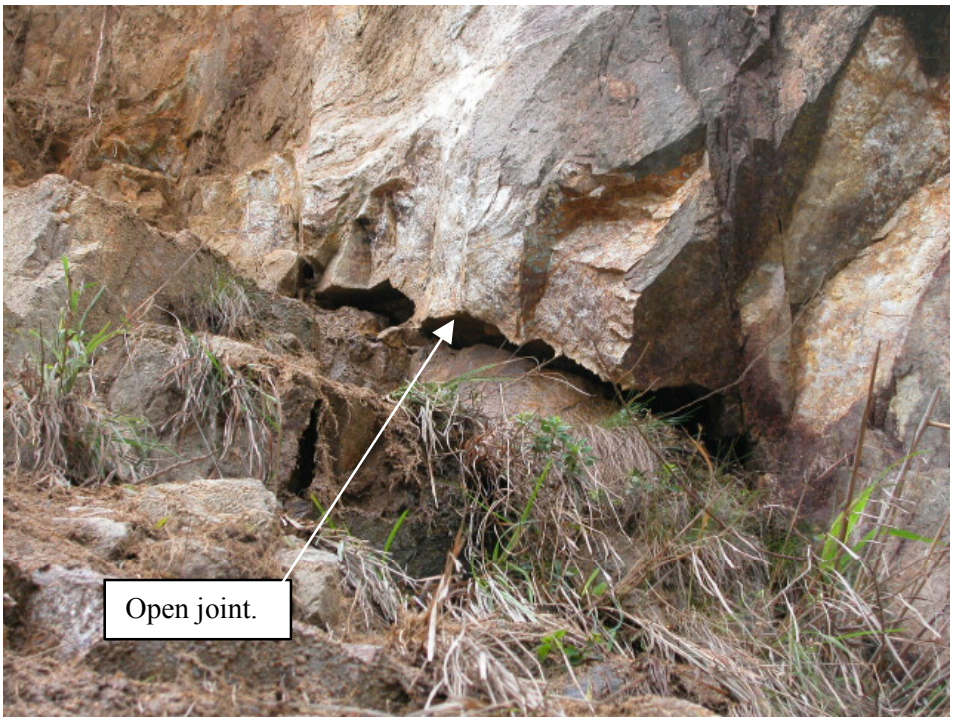

Plate 13 - Detailed View of Open Joint Adjacent to the Source of the Rockfall (Photograph taken on 24 May 2002 by HCL)

Plate 14 - View of the Eastern Portion of Slope No. 11NE-A/C284 Showing a Series of Large Potentially Unstable Blocks (Photograph taken on 24 May 2002 by HCL)

Plate 15 - View of Potentially Unstable Blocks Located at the Central Portion of Slope No. 11NE-A/C284 (Photograph taken on 3 July 2002 by HCL)

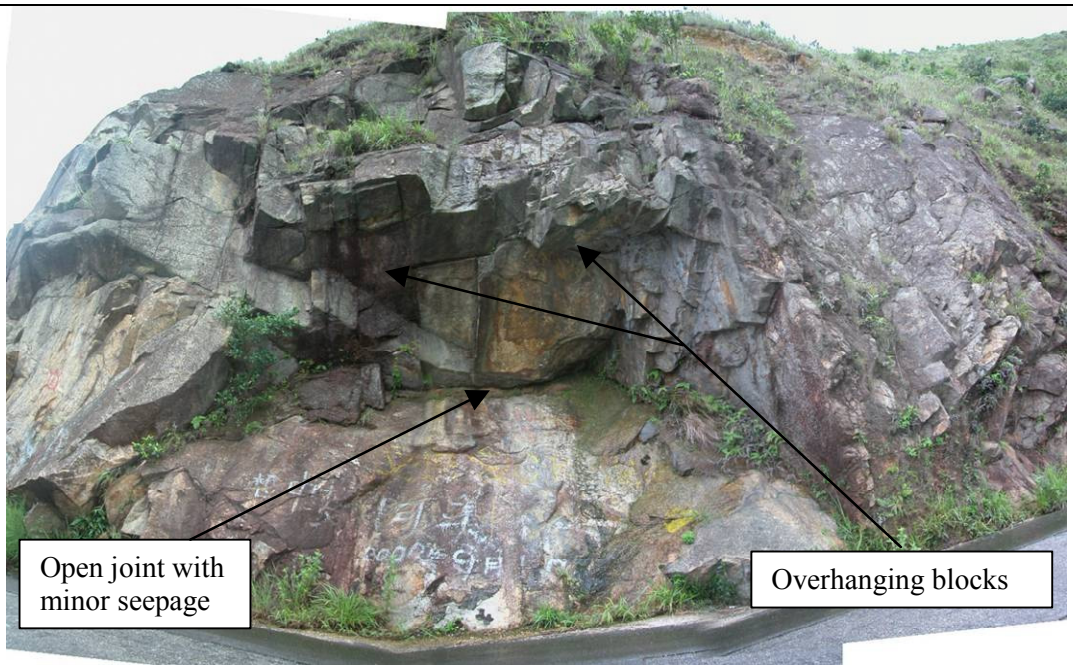

Plate 16 - View of Overhanging Blocks Located at the Central Portion of Slope No. 11NE-A/C285 (Photograph taken on 3 July 2002 by HCL)

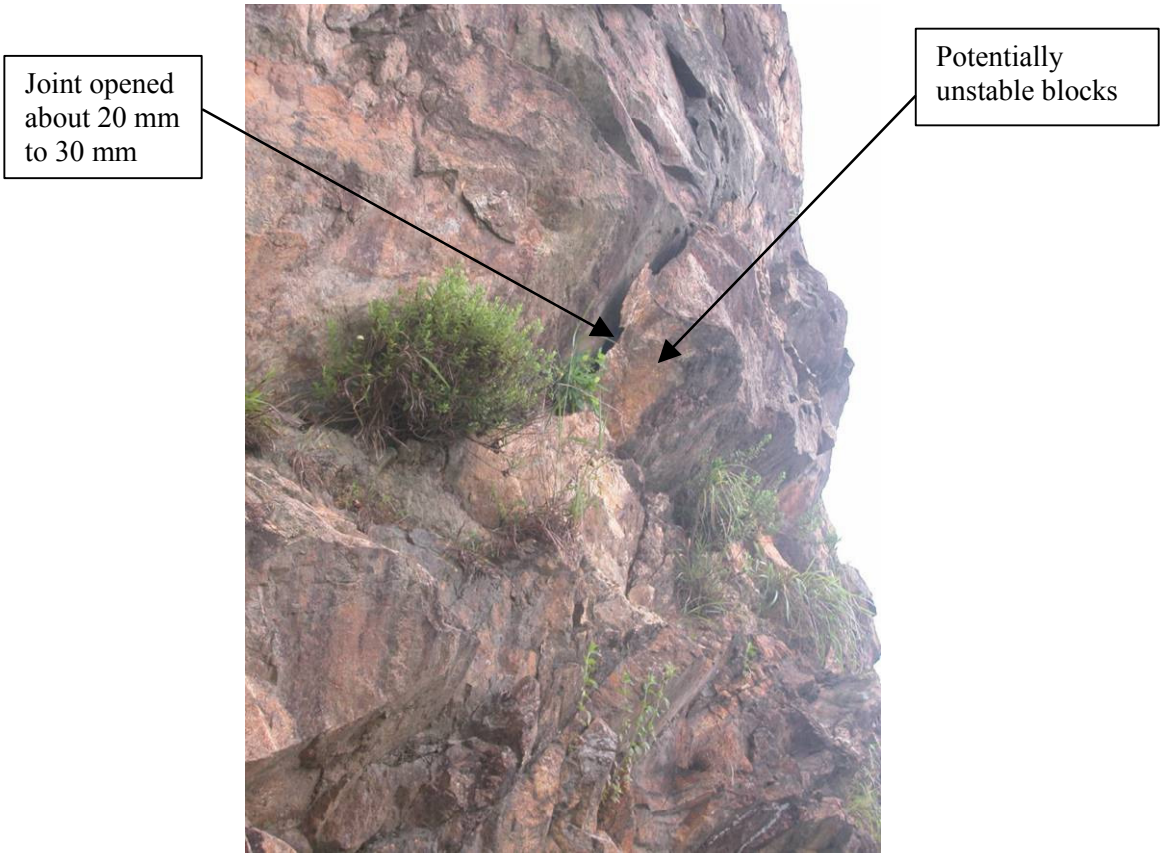

Plate 17 - View of Potentially Unstable Block Located at the Central Portion of Slope No. 11NE-A/C281 (Photograph Taken on 3 July 2002 by HCL)

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Plate 18 - View of Potentially Unstable Blocks Located at the Crest of Slope No. 11NE-A/C281
(Photograph taken on 23 July 2002 by HCL)

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

AERIAL PHOTOGRAPH INTERPRETATION (API) REPORT
SLOPE NO. 11NE-A/C284

1. INTRODUCTION

As a result of a rockfall (GEO Incident No. 2002/05/0030) that occurred at about 8:30 p.m. on 22 May 2002 on slope No. 11NE-A/C284, HCL was requested to carry out an API of the subject slope and the surrounding hillside.

The primary aim of the API was to identity signs of instability in recent and historic aerial photographs.

2. SUMMARY OF OBSERVATIONS

The subject slope was already formed and Shatin Pass Road completed at the time of the earliest available aerial photograph in 1949. Signs of previous instabilities were observed above the crest of the subject slope and along an unlined drainage ditch excavated upslope of the cut slope in the 1963 photographs. Also in the 1963 photographs, a curved lineament was observed above the eastern end of the slope. Possible interpretation of the lineament is that it is either a tension crack or an anthropogenic feature. Field inspection would be required to confirm the origin of the feature as an anthropogenic feature. Similar lineaments are also visible on both the adjacent cut slopes (slopes Nos. 11NE-A/C281 and 11NE-A/C285).

In 1999, a minor failure scar (subsequently sealed with shotcrete) was identified at the crest of slope, about 5 m to the west of the recent rockfall.

Significant seepage, evidenced by pooling of water on the road, was observed at the location of the recent rockfall and at two other locations below the subject slope on many of the aerial photographs reviewed.

3. OBSERVATIONS

Date of Photograph GEO Photo No(s) Altitude	Observations
19 May 1949 Y01811-Y01813 8000’	High altitude, poor quality low resolution photographs. Shatin Pass Road has been completed. The subject slope is located just off the coverage of the photographs.
27 January 1963 Y08247-Y08249 2700’ Y08679 - Y08680 2700’	Slope No. 11NE-A/C284 is clearly visible, and the slope profile appears to be similar to its present extent. The specific rock block involved in the recent failure cannot be identified. A prominent lineament, interpreted as an unlined drainage ditch, is

Date of Photograph GEO Photo No(s) Altitude	Observations
	visible some 5 m to 20 m above the crest of the slope No. 11NE-A/C284 (Figures A1 and A2). The unlined ditch is connected to a concrete lined channel at the eastern end of the slope and into an unlined drainage ditch leading to a concrete catchpit at the western end. Similar unlined drainage ditches are visible above slopes Nos. 11NE-A/C285 and 11NE-A/C281 located to the west and east of the subject slope respectively. Exposed rock covers much of the natural terrain above Shatin Pass Road. The rest of the hillside is generally thinly vegetated with grasses and occasional small shrubs. Much of the hillside below the road is sparsely wooded. Two landslide scars (both approximately 12 m long and 4 m wide) are visible above the crest of the western end of the subject slope (labelled as 63A and 63B on Figure A1). A series of minor scars are also visible along the drainage ditch (labelled as 63C to 63E on Figure A1). Similar minor failures are visible along the drainage ditches above the adjacent cut slopes (labelled as 63F and 63G on Figure A1). A small shallow depression is visible above the crest of the slope No. 11NE-A/C284 located about 2 m above the recent rockfall (Figure A1). The depression possibly indicates the location of a relict landslide, involving failure of a rock slab from above the crest of the subject slope. A 25 m long curved lineament is visible about 10 m above the western end of the subject slope, located about midway between the crest of the slope and the drainage ditch above (Figures A1 and A2). The lineament appears to form a small step (about 1 m high) that traverses the hillside. The original of the lineament is not known. A field inspection would be required to confirm the actual origin of the feature. Similar, but less defined lineaments, are also visible above the adjacent cut slopes (Figure A1). A series of photolineaments are visible crossing the natural hillside surrounding the subject slope (Figure A1), the most prominent of which follows the natural drainage line to the east of the subject slope. A narrow photolineament, possibly formed by the exposed daylighting edge of a sheeting joint, traverses the eastern end of the subject slope (Figure A2), at the location of the recent rockfall. Possible seepage points, evidenced by dark toned streaks on the road surface consistent with flowing or pooling water are visible at three locations below the subject slope. The seepage points are labelled as Seepage Point 1, 2 and 3 on Figure A1.

Date of Photograph GEO Photo No(s) Altitude	Observations
10 December 1973 6858-6859 3000’	With the exception of an increase in vegetation cover over the area of natural hillside upslope of Shatin Pass Road, no significant change is visible. A moderately large failure (marked as 73A on Figure A1) is visible at the western end of slope No. 11NE-A/C281. The failure is about 12 m long by 7 m wide and appears to have affected both the cut slope and the natural hillside above. The failure scar appears partly vegetated indicating the failure probably occurred a number of years earlier. A second failure (about 8 m long and 3 m wide) is visible at the eastern end of slope No. 11NE-A/C281. The failure scar appears very recent and a debris trail is visible downslope of the road. The location of the failure is outside the coverage of Figure A1. Possible seepage was observed at seepage points 1, 2 and 3 (Figure A1).
17 December 1974 10449-10451 4000’	No significant change visible to the subject slope. Possible seepage was observed at seepage points 1, 2 and 3 (Figure A1).
30 June 1976 14309-14311 2500’	No significant change visible to the subject slope. The natural hillside between Shatin Pass Road and the ridgeline above shows evidence of a recent hillfire. Minor patches of surface erosion are visible along the ridgeline. Possible seepage was observed at Seepage points 1, 2 and 3 (Figure A1).
4 October 1976 15421 4000’	Single high altitude photograph. No significant change visible to the subject slope. Possible seepage was observed at Seepage points 1, 2 and 3 (Figure A1).
21 December 1977 20215-20216 4000’	No significant change visible to the subject slope. Possible seepage was observed at Seepage point 3 (Figure A1).
7 November 1978 23083-23084 4000’	No significant change visible to the subject slope. Possible seepage was observed at Seepage points 1, 2 and 3 (Figure A1).

Date of Photograph GEO Photo No(s) Altitude	Observations
10 February 1981 36583-36585 5500’	An area of natural hillside located between the drainage ditch above the subject slope and the ridgeline above shows evidence of a recent hillfire. Possible seepage was observed at Seepage points 1 and 3 (Figure A1).
1983 50632-50634 5000’	No significant change visible to the subject slope.
21 November 1988 A15691-A15692 4000’	A failure scar (about 4 m long and 4 m wide) is visible on the eastern end of slope No. 11NE-A/C285 (labelled as 88A on Figure A1). Above the location of the failure minor areas of surface erosion are visible on the hillside (Figure A1). Debris washout from these areas of surface erosion has formed thin light toned trails running down the hillside. The road surface of the bridge at the eastern end of the subject slope is light toned indicating either the road surface has been replaced or the bridge re-built. Possible seepage was observed at Seepage points 1, 2 and 3 (Figure A1).
23 October 1998 A48436-A48438 4000’	A footpath located about 60 m above the crest of the subject slope is under construction. A fresh area of shotcrete about 20 m by 10 m has been placed over the western end of slope No. 11NE-A/C281. The natural hillside above the subject slope has recovered from the earlier hillfires and is covered in dense grass and small shrubs. The hillside below Shatin Pass Road is generally densely wooded. Possible seepage was observed at Seepage point 3 (Figure A1).
27 October 1999 A50529-A50530 4000’	At the crest of the rock slope a light toned area (about 4 m by 4 m) is visible about 5 m west of the location of the recent rockfall. This is probably a minor failure or an area recently shotcreted (marked as 99A on Figure A1). The footpath above the crest of the slope has been completed. Possible seepage was observed at Seepage points 1 and 3 (Figure A1).

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Date of Photograph GEO Photo No(s) Altitude	Observations
11 December 1999 CN25305- CN25306 4000’	No significant change visible to the subject slope. Possible seepage was observed at Seepage points 1 and 3 (Figure A1).
2000 CN27560 4000’	Single photograph. No significant change visible to the subject slope. Possible seepage was observed at Seepage points 1, 2 and 3 (Figure A1).
21 January 2001 RW0854-RW0856 16000’	Infrared high altitude photographs. Due to high altitude and aspect of photographs, no significant detail of the slope can be identified.

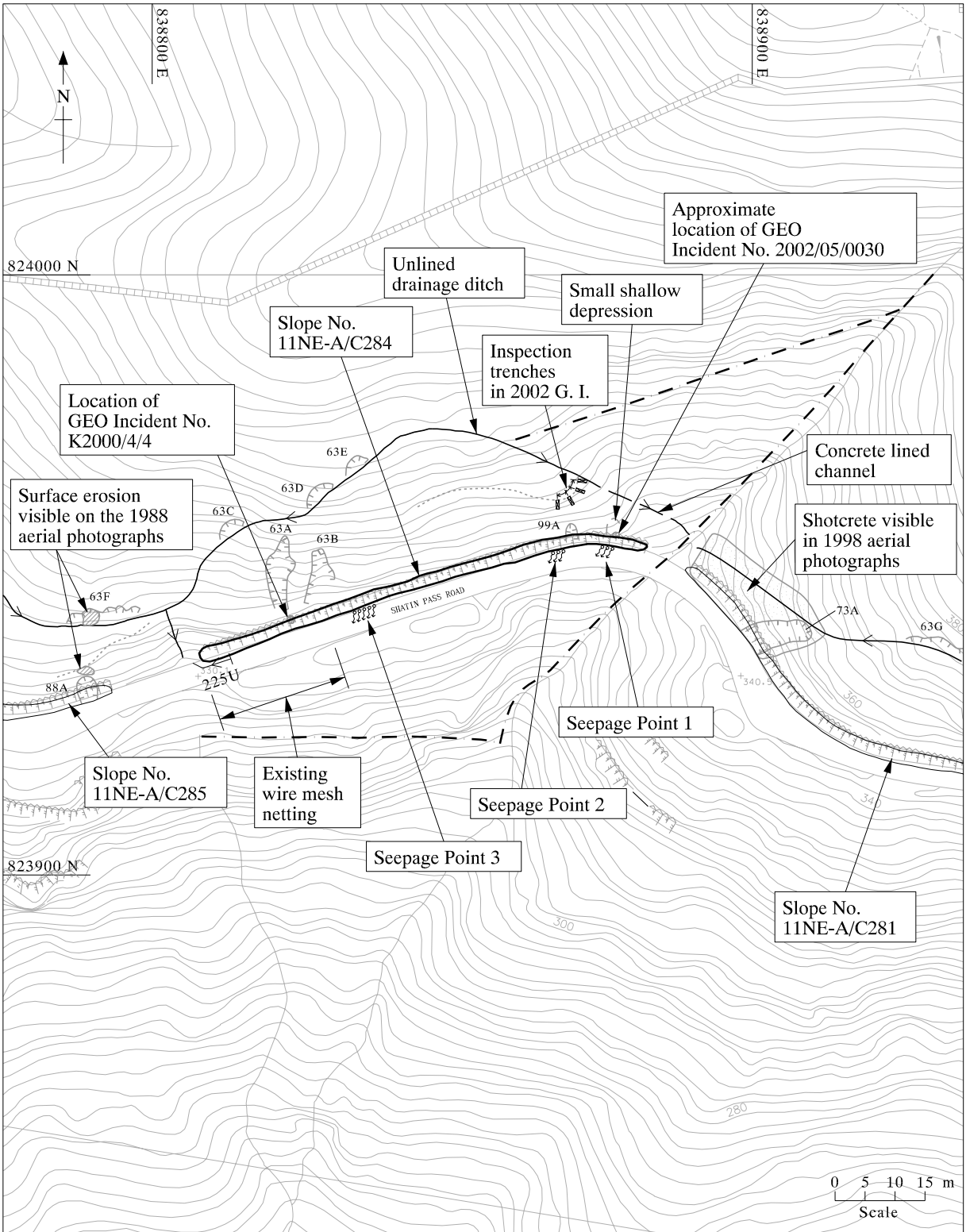

Figure A1 - Feature Identified During the API

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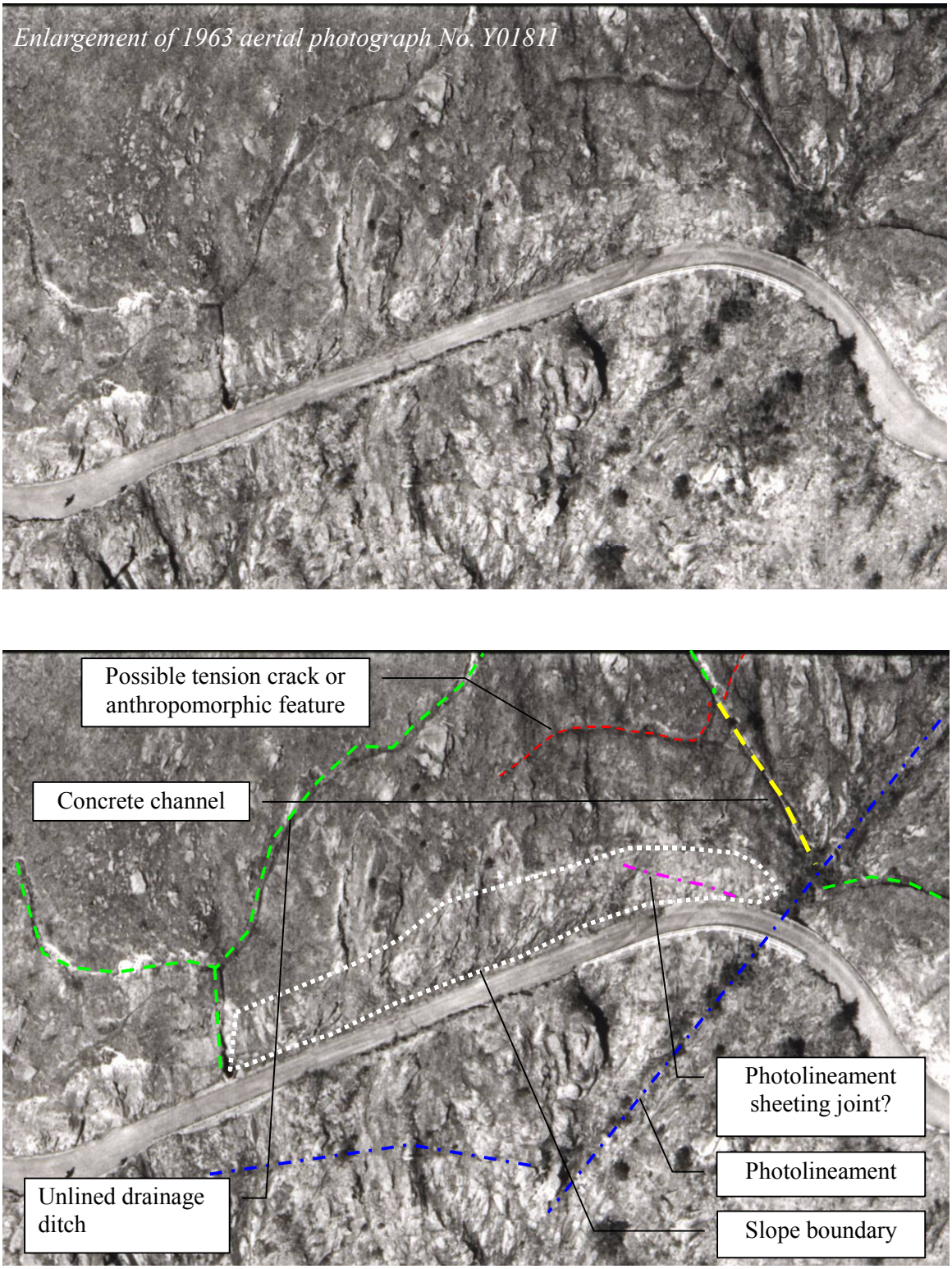

Figure A2 - Possible Tension Crack above Slope No. 11NE-A/C284
Observed in the 1963 Aerial Photograph

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GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

writing to
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- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 2	Model Specification for Reinforced Fill Structures (1989), 135 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/96	Pile Design and Construction (1996), 348 p. (Reprinted, 2003).
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents